EXHIBIT K

Report

To

Napoli Bern Ripka Associates LLP

Concerning

Norma Fiorentino, et al. v. Cabot Oil and Gas Corporation et al.

Case No. 3:09-cv-02284-JEJ

By

Anthony R. Ingraffea, Ph.D., P.E.

February 13, 2012

1.0 INTRODUCTION: FLUID MIGRATION MECHANISMS DUE TO FAULTY WELL DESIGN AND/OR CONSTRUCTION

An overall description of mechanisms by which oil and gas wells can develop gas and other fluid leaks can be found in Dusseault *et al.* (2000). These mechanisms can be exacerbated with repeated pressurization of the casing, with open-annulus sections along the casing, and with high gas pressures encountering curing cement or entering such open-hole sections. All of these exacerbating factors lead to more rapid occurrence and upward growth of circumferential fractures, essentially disbonding, in the rock-cement and /or the cement-casing interface.

A schematic depiction of the phenomenon of gas, or additional fluid, migration upwards along a wellbore is presented in Figure 1a, for the simplest case of bypass by disbonding along the surface casing. Figure 2 is a close-up schematic showing other possible fluid pathways. Additional layers of casing and attendant cement interfaces, present in the defective wells in question, do not eliminate these phenomenon; they may, in fact, increase its likelihood. Figure 3 is a snapshot of yet another situation in which an intermediate casing annulus is left un-cemented, but open to a shallow gas source.

These phenomena are not rare in the oil and gas industry. Data on failure rates for cement jobs leading to sustained casing pressure and possible fluid migration into USDW can be found, for example, in Figure 4 from Brufatto *et al.* (2003), who state:

> "Since the earliest gas wells, uncontrolled migration of hydrocarbons to the surface has challenged the oil and gas industry…many of today's wells are at risk. Failure to isolate sources of hydrocarbon either early in the well-construction process or long after production begins has resulted in abnormally pressurized casing strings and leaks of gas into zones that would otherwise not be gas bearing".

In their statistical analysis of information about nearly 315,000 oil and gas wells, Watson and Bachu (2009) state:

> "Low cement top or exposed casing was found to be the most important indicator for SCVF/GM. The effect of low or poor cement was evaluated on the basis of the location of the SCVF/GM compared to the cement top... the vast majority of SCVF/GM originates from formations not isolated by cement."

Figure 5 shows data gathered by Watson and Bachu that is consistent for young wells with that shown in Figure 4. Note that all these citations are from industry sources. It should be noted that, even with ongoing technological and chemistry improvements in cement and in cementing, loss of wellbore integrity is still common. For example, during 2011, Cabot drilled 68 new Marcellus wells in Pennsylvania, and was cited by PA DEP seven times for "Failure to report defective, insufficient, or improperly cemented casing w/in 24 hrs or submit plan to correct w/in 30 days". Chesapeake Appalachia drilled 279 wells and was cited 24 times for the same violation.

1.1 Prevalence of Fluid Migration from Faulty Wells

The science on contamination of drinking water from shale gas drilling, fracing, and production, is recent, ongoing, and incomplete. A peer-reviewed, archival journal study from Duke University (Osborne, *et al.*, 2011) found apparent migration of substantial amounts of methane from gas wells to private water wells as far out as 1000m in the Marcellus play in Pennsylvania. There are several other studies on this topic underway in Pennsylvania (as of late 2011). Also, the U.S. Environmental Protection Agency (EPA, 2011) recently released a preliminary report from an on-going study in Pavilion, WY that suggests that substances used in fracing might migrate into adjacent water-bearing strata. The study also found extremely clear evidence that there had been migration of methane from gas wells to nearby drinking water wells - likely caused by deficient cement jobs. Inadequate well construction and, of course, spills have been implicated in many states in a large number of cases of migration of drilling related substances into nearby drinking water.

Along with these fairly direct evaluations of the migration of methane and other substances, industry sources have asserted that private water wells are often contaminated by "naturally occurring" methane. This is often presented in an apparently analytical but confusing way suggesting that the appearance of methane in drinking water wells is sort of "common" and thus unlikely related to any gas well drilling. Such presentation fails nearly entirely to, first, distinguish between dangerous/hazardous levels of methane in water (10 mg/L or more), and

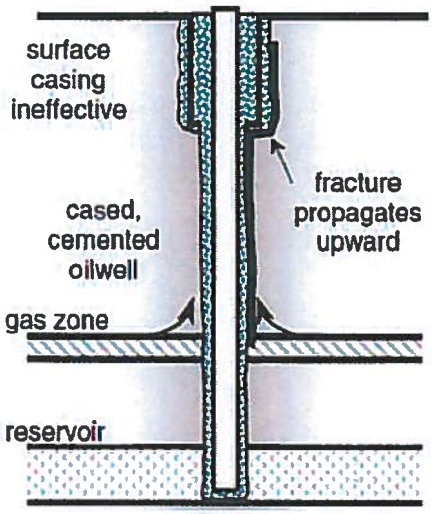


Figure 1. Simplified schematic showing phenomenon of upward gas migration along a casing string. From Dusseault *et al.*, 2000.

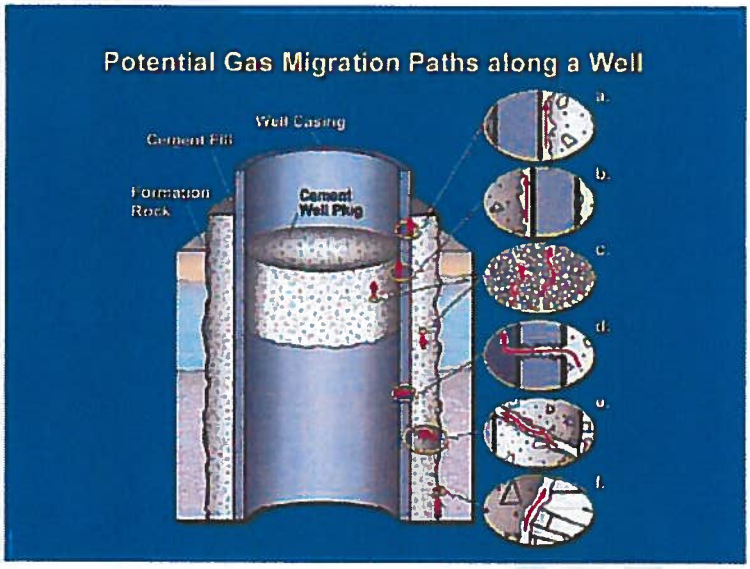


Figure 2. Schematic of details of possible fluid migration paths.

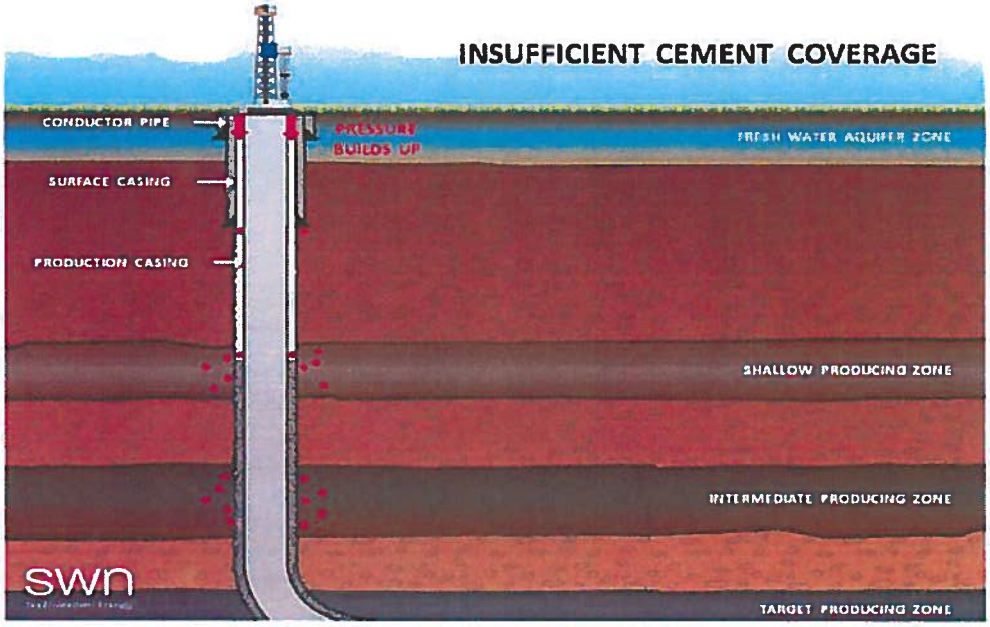
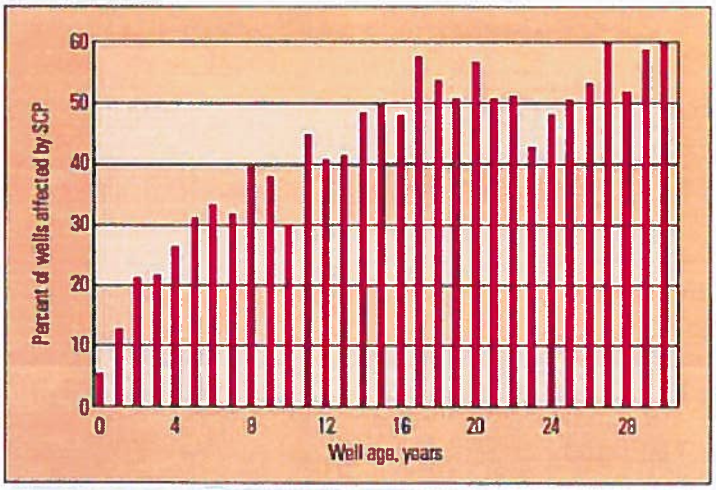


Figure 3. Depiction of entry of gas from a shallow source into an un-cemented annulus, leading to sustained casing pressure and migration of fluids into a USDW. From Boling (2011).



^ Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.

Figure 4. Data on frequency of occurrence of sustained casing pressure (SCP). From Brufatto *et al.* (2003).

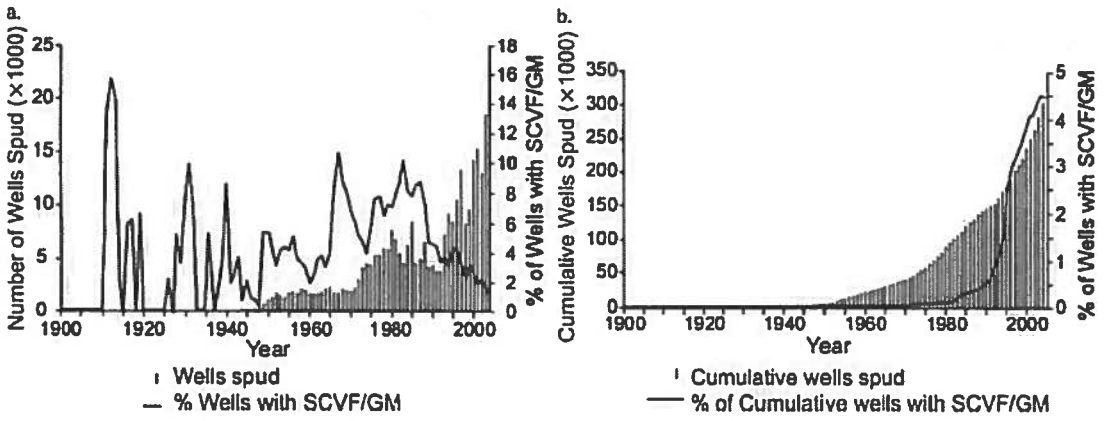


Fig. 8—Historical levels of drilling activity and SCVF/GM occurrence in Alberta: (a) by year of well spud and (b) by cumulative wells drilled.

Figure 5. Data on frequency of occurrence of sustained casing vent flow (SCVF) From Watson *et al.* (2009).

much lower levels that are not generally taken to be of concern. Second, ignores the prevalence or likelihood of having a dangerous "natural" level of methane in drinking water. Third, ignores any time line: has there been any significant change in the concentration of methane concurrent with the beginning of nearby gas field development.

The New York DEC's data (NYS rdSGEIS, pg. 4-39) make crystal clear that for a 2010 sample of water wells (n=46) in the "Delaware, Genesee, and St. Lawrence River Basins," presumably not near gas wells, just 2% of the wells had a dangerous level over 10 mg/L. One well had a level of 22 mg/L; the remaining wells then had an average level of 0.31 mg/L. This roughly 2% "normal" risk has been confirmed repeatedly in studies in PA, in the Southern Tier of NY (1450 water wells, USGS, 2010), in Alberta, Canada (360,000 wells, Griffiths, 2007) and by both independent investigations and by testing by gas drillers (e.g., Boyer, *et al.*, 2011). None of these findings suggest, in any way, that dangerous levels of methane are at all common in rural private water wells. Thus, a fairly strong implication is that, if and when methane does occur at high levels in water wells near gas drilling, it is likely due to some aspects of gas drilling, fracing and/or production operations themselves. This is consistent with both the Osborn, *et al.* (2011) study and the EPA Pavilion (2011) preliminary report. Exact migration mechanisms are not yet

completely clear in each case, but the potential well failure mechanisms described in the previous section are often implicated.

2.0 EVALUATION OF RECORDS OF DEFECTIVE WELLS

I have reviewed well records for certain gas wells drilled by Cabot in the Dimock, PA, area and declared "defective wells" by the PA DEP (Consent Order, 2009; 2010a; 2010b). Below, I evaluate these records starting with those ordered plugged by PA DEP, note faulty designs and construction events, particularly within the framework of industry knowledge as noted above, and opine of the possibility that such could cause migration of natural gas or other fluids into the PA DEP defined "affected water supplies".

2.1 BAKER 1

Baker 1 was spud on August 13, 2008 (Well History, Baker 1), and intended for the Marcellus shale formation. A major problem in the *design of this well* was the intention of leaving an open 7'' x 4.5" annulus between 1534' and 3100'. A major problem *during drilling of this well* was lockup of cement in the 7" x 4.5" annulus, resulting initially in about 5500' of open annulus, from about 7100' to 1534', between about 9/1/2008 and 10/23/2008. The cement job had been designed to fill the annulus up to 3100', but a Schlumberger cement log determined that the cement had risen only about 200 feet up the annulus. During this period, this annulus was open to gas shows that had been documented at 5928' and 6886'. See Figure 3, above. Subsequent attempts to squeeze cement into this open annulus, up to a level of 5490', required higher than expected injection pressures, indicating that the annulus was already pressurized, and the squeeze still did not completely fill the unfilled segment. Subsequent measurements at the surface confirmed the continued presence of high pressure gas in this annulus. During this period of open annulus and abortive attempts to fill it, this well was in violation of 25 PA Code 78 Oil and Gas wells (bold italicization mine):

> § 78.83. Surface and coal protective casing and cementing procedures.
>
> (g) If additional fresh groundwater is encountered in drilling below the permanently cemented surface casing, the operator shall protect the additional fresh groundwater by installing and cementing a subsequent string of casing or other procedures approved by the Department to completely isolate and protect fresh groundwater.

> The string of casing may also penetrate zones bearing salty or brackish water with cement in the annular space being used to segregate the various zones. ***Sufficient cement shall be used to cement the casing at least 20 feet into the permanently cemented casing.***

Baker 1 was found to have excessive pressure in an annulus, and declared a "defective well" by PA DEP, and was ordered plugged in the April 15, 2010 Consent Order. Baker 1 is within 1000' of the affected water supply of Craig Sauntner, and within 1300' of the affected water supplies of Norma Fiorentino and Timothy Maye. Mr. Sauntner reported significant levels of methane and sediments in his well water on 11 Sept 2008. Ms. Fiorentino's well exploded on January 1, 2009. Note that there was a fresh water show at 990' during drilling of this well.

In my expert opinion, I believe it is highly likely that:

- Because of cement lockup on 1 Sept 2008, the open 7in. x 4.5in. annulus became gas pressurized;
- Despite subsequent cement squeezing to a height of 5490', gas continued to pressurize this annulus;
- Gas pressure failed the cement-to-rock interfaces above the 1534' level; and
- Gas and other fluids, either associated with drilling or native, were able to enter fresh water aquifers above this level, including those of the above-cited affected parties.

3.0 GESFORD 3S

The original Gesford 3 was spud on September 25, 2008 (Well History, Gesford 3) and intended for the Marcellus shale formation. The first attempt to drill Gesford 3 failed. During the first attempt, there were fresh water shows at 100' and 350', and only the conductor casing could be installed, first to 30', then to 190'. The conductor casing was cemented, but drilling fluid circulation outside this casing was observed on October 6, 2008, after cementing, and while repeated drilling to a depth of 595'. After collapse of the borehole for 30' above the lost drill bit, the Cabot home office ordered the plugging and abandonment of this abortive well on October 8, 2008. The well was plugged on October 9, 2008. (See my review of Gesford 9DDV, below, for continuation of the history and performance of the original Gesford 3). The home office ordered the rig skidded to a new spud site for the second Gesford 3S well.

Drilling of the second, Gesford 3S, well commenced on October 10, 2008 and was not completed to a depth of 7058' until January 3, 2009. This very long period of drilling was highlighted by many drilling difficulties resulting from borehole instabilities, a casing seat failure, many equipment failures, two cement squeeze jobs, and repeated cycling of casing pressure after some cementing procedures had been completed. There was a natural gas show at about 1500'. This well was 2-stage fraced on March 20, 2009.

The initial design of this well left an open, innermost annulus (7in. x 4.5in.) above the 5293' depth. This annulus was later squeezed on April 4, 2009, to a depth of about 880'. Two cement bond logs were run on April 6, 2009, and both found substantial indications of faulty cement bond with the casing. The first log, under no casing pressure, indicated no cement contact with the casing above about 4700'. The second log, under pressure, indicated only 70 to 90% contact around the level of gas show, about 1500'.

Gas was observed, and videotaped, bubbling in the cellar of this well during the period May 28 to June 29, 2009. Gesford 3S was found by PA DEP to have "...insufficient or improper cemented casings that allow gas to vent between various cemented casings/and/or from behind the surface casing", declared a "defective well", and was ordered plugged in the April 15, 2010 Consent Order. Gesford 3S is within 1000' of the affected water supply of Nolan Ely and Victoria Hubert, and within 1300' of the affected water supply of Michael Ely. Nolen Ely reports his family feeling cramping, and notices something wrong with his water in October, 2008.

In my expert opinion, I believe it is highly likely that:

- Because of the failure to isolate the first Gesford 3 well from water shows at 100' and 350', for a period of about 3 weeks, contamination of these aquifers with drilling mud or other well drilling materials could have occurred;
- Because of the casing seat failure on the second, Gesford 3S well, the 20in. x 13in. annulus failed and had to be squeezed. In that failed annulus period, contamination of USDW with drilling mud or other drilling materials could have occurred;

- Despite subsequent cement squeezing of the damaged 20in. x 13in. annulus, it was a failed cement job, and allowed continued gas venting to the surface;
- Despite squeezing of the 7in. x 4.5in. annulus, and even when bond logging under pressure, a tactic known to produce false readings of bond integrity, that annulus also had a failed cement job;
- Because the cement job in the 7in. x 4.5in. annulus was grossly defective, the gas show at about 1500' could pressurize this annulus, cause disbonding of cement-to-rock contacts in this and other annuli, and allow gas and other fluids to enter fresh water aquifers above this level, including those of the above-cited affected parties.

4.0 Gesford 9DDV

I have reviewed the well records made available to me for Gesford 9DDV (drill deeper) which was re-spud as a workover of the original Gesford 3 on or near August 20, 2009 (Well History, Gesford 9DD), and intended for a shallow, 2000 ft. TVD, "Upper Devonian" shale formation to intercept shallow gas flow that had been found in its area. This admission proves that Cabot was aware of high-pressure shallow gas in the area of the affected water wells. I must note that the well history records and other reports I have been shown for this well are incomplete and inconsistent. These records show this shallow well was ultimately drilled to a depth of 1911ft, and turned over to production on November 3, 2009. They also show that during April 2010, DEP and Cabot representative inspections occurred that appear to indicate problems with this well. These become defined in the November, 2009 Consent Order where PA DEP determined that Gesford 9DDV had insufficient or improper cemented casings allowing gas to vent between casings.

A Cabot interoffice memo of August 11, 2009 describes past and proposed activities with this well as:

> "The #3 was drilled to approximately 900' when the drill string became stuck. Efforts to free it were unsuccessful and the drill pipe was backed off leaving the bit at 595' with five drill collars for a top of fish at 442'. Two cement plugs were pumped to plug the well to the surface. Due to shallow gas the well began leaking around the 13" surface casing. Beginning January 2009 the wellbore was reentered and after several attempts the

drill collars and bit were recovered. Once the fish was recovered, 9 5/8" casing was run and cemented at 858' and the well temporarily abandoned."

The well history then begins only on August 20, 2009. I have not been provided well history for the January to August 20, 2009 period, so cannot evaluate what might have been done to set, or not, new conductor casing, and cement, or not, such new casing. I have been provided three well schematics, all labeled "Gesford 9". One dated August 10, 2009, depicts a two-casing design with a 16" conductor and a 9-5/8" surface casing to 2000' KB. I suspect this might have been the original intent for Gesford 3. The second, dated August 13, 2009, depicts a three-casing design with a 13-3/8" conductor, 9-5/8" surface casing to 857' KB, and 5-1/2" production casing to 2000' KB. The third schematic, part of Cabot's "Integrity Testing Discussion", is similar to the second, except it eliminates the 5-1/2" production casing, but includes 7" casing to 1435' KB, and then 2-3/8" tubing to 1542' KB. This schematic also notes that drilling on Gesford 3 was suspended on March 3, 2009, after installation and cementing of the 9-5/8" casing.

As noted above, the well history for Gesford 9DD provided to me only commences on August 20, 2009, with drilling re-commencing on August 21, at this time for a 8-3/4" hole for installation of 7" casing. This casing installation was completed to 1435' KB; this indicates that both design well schematics labeled "Gesford 9" are incorrect. This history describes numerous problems with drilling and completion of this well, and is missing days of reporting, notably September 15-16. It uses, word-for-word, the report of September 14 on September 17. There is no reporting again until October 8, 2009. There is no report of a cement bond log being run before the well was turned over to production on November 11, 2009.

In the November 4, 2009 Consent Order and Agreement, Gesford 9DD was found to have insufficient or improper cemented casings. A cement bond log was finally run on this well on January 30, 2010. I have reviewed Cabot's Gesford 9DDV integrity testing discussion from Monday, February 1, 2010. These records show that fresh water was encountered at depths of 100 ft. and 350 ft. during initial drilling of Gesford 3. They also admit that bubbling from the 9-5/8in. x 7in. annulus was occurring at that time of integrity testing, and that the 13-3/8in. x 9-5/8in. annulus was being isolated and vented to stop it also from SCP. This bond log indicated

defective cementing, and by the April 15, 2010 modification to the consent order and agreement, the well was ordered plugged.

There were also a surface spill incident and a surface leakage incident associated with this well. On August 18, 2009, 60-80 gallons of diesel fuel were spilled onto the pad and under the reserve pit liner.

Gesford 9 is within 1000' of the affected water supply of Nolan Ely and Victoria Hubert, within 1300' of the affected water supply of Michael Ely, and within about 1500' of the affected water supply of Bill and Sheila Ely. Nolen Ely reports his family feeling cramping, and notices something wrong with his water in October, 2008. Bill and Sheila Ely discovered they could ignite their tap water on January 18, 2009.

In my expert opinion, I believe it is highly likely that:

- The repeated failed attempts to drill and cement the original Gesford 3 well caused failure of the cement job on that well and led to contamination of affected water supplies from shallow gas sources that were known by Cabot to exist below this pad.
- The re-entering and deepening of the original Gesford 3 well to attempt to create Gesford 9, exacerbated cement problems with this well and led to observed annular gas flows.

5.0 Ratzel 2H-NW

Ratzel 2H-NW was spud on May 17, 2009 (Well History, Ratzel 2H-NW) and intended for the lower Marcellus shale formation. Problems on this well began with setting the conductor casing, which was initially set at 41' KB, then lifted 3', then driven to 46' KB, with incidents of circulation to its annulus and two internal cement pours, and no apparent attempt to re-cement the conductor annulus. After drilling through cement in the conductor a second time, fresh water was encountered at 105' KB. Trouble continued when, at a drilling depth of 142' KB, "hit conductor tight spot, knocking conductor downhole", again causing circulation up the conductor annulus. An attempt to drive 13-3/8in. surface casing stalled at 127' KB, and its annulus was then cemented to surface. Drilling continued, with a water encounter at 710' KB, on the way to

installing 9-5/8" surface casing to 847' KB. Note that the design of this well intended surface casing to a depth of only 400'.

Drilling proceeded as expected until installation and cementing to surface of 7" casing to a depth of 1479' and welding of casing head to it. At this time, May 27, 2009, the well record notes "...accidently dropped BOP stud down hole". The next three days were spent fishing and attempting to mill out the bolt. This was the first of two major problems which required extensive milling of steel components inside a casing string.

The entire 4-1/2"-to-rock annulus was not cemented. Rather, a cement port collar was accessed at about 6200' KB and cement was injected into this annulus from that level. A CBL indicated a poor cement job: coverage of "70-90% bond from 6208'-5600', 50-70% bond from 5600'-2350' ", and with top-of-cement estimated to be at 2350', not the intended 1000'.

Drilling was completed on July 13, and fracing of 5 of the intended 9 stages was completed on August 18. The second major problem occurred after the well was turned over to production, and involved a patch to the 4-1/2" casing starting at about 6100' KB. Over a period of ten days starting on September 11, crew made many efforts to mill out the casing patch that had been installed to support partial cementing of the 4-1/2"-to-rock annulus. An additional 5 days of diagnostics and requests for instruction from Engineering resulted in a cement bond log being made on September 26 which found a "possible hole" in the 4-1/2" casing between 6194' and 6196' KB.

Further efforts to mill through the "tight spot" caused by the faulty casing patch included repeated heavy pulling on stuck equipment in the casing. Removal of all undesirable materials from this casing by milling was finally completed on October 20.

The Ratzel 2H well is within 1000' of the affected water supplies of Stover and Salsman. In my expert opinion, I believe it is highly likely that:

- The cement job in the outermost, 4-1/2"-to-rock annulus was ineffective. First, top-of-cement in this annulus was designed to be 1000' KB, but was estimated to be at 2350'

KB, leaving this annulus open to any intermediate (but curiously unreported) gas flows between this level and 1492' KB, like those noted by Cabot on adjacent Ratzel 1H at 1558' (25,000cf/d), 1775', and 2240'. Next, the cement job below 2350' was poor, as indicted by the results of the CBL. The cement was likely further damaged by the movements of the casing due to repeated attempts to dislodge stuck equipment in this casing. Finally, Cabot's well record indicates the likelihood of a hole in the 4-1/2" casing, likely due to failure of the casing patch and/or the prolonged milling operations employed to clear this casing.

- Because the cement job in the 4-1/2"-to-rock annulus was grossly defective, the intermediate gas shows could pressurize this annulus, cause further disbonding of cement-to-rock contacts in this and other annuli, and allow gas and other fluids to enter fresh water aquifers above this level, including those of the above-cited affected parties.

5.0 Ratzel 3V

Ratzel 3V was spud on April 12, 2009 (Well History, Ratzel 3V), and intended for the Marcellus shale formation, and almost immediately ran into trouble setting the conductor casing. Alignment problems necessitated attempted removal of the original, already cemented 20" conductor. Four days of fishing, attempted resetting, and unsuccessful attempts to clean the annulus were required to finally set the 20" conductor, initially, to 42' KB. However, additional problems resulted in the 20" casing dropping 2 feet, then having to be hammered an additional 9 feet before reaching its final setting depth. During this period, the "...hole made too much water, and mud kept falling back in annulus". Clearly, the near-surface aquifer was being disturbed. Moreover, there is no indication that the 20" conductor was ever re-cemented after its last hammering into place.

The well was drilled to a TD of 6980' KB. A cement bond log from TD to surface showed "...good cement from TD to 4520', poor cement from 4520' to 3170' and good cement from 3170' to 700'." No mention is made of cement bond quality above 700', although Cabot noted gas shows on adjacent Ratzel 1H at 1558' (25,000cf/d), 1775', and 2240'. The well was completed in two stages between 6734'-6884' and 6530'-6650', and was turned over to production on August 27, 2009.

Subsequently, Cabot reported (November, 2010) a gas pressure of 100psi in the 4-1/2" to 7" annulus, and a pressure of 15psi in the 7" to 9-5/8" annulus.

The Ratzel 3V well is within 1000 feet of the Roos affected water supply. In my expert opinion, I believe it is highly likely that:

- The existence of fresh water shows at 25', 235', and 795', likely unreported encounters with gas shows, the poor or unreported cement bond quality over substantial lengths of the 4-1/2" casing, and the unknown cement bond quality around the other casings allowed gas and other fluids to enter fresh water aquifers, including those of the above-cited affected party.
- The poor handling of the construction of the conductor casing likely caused temporary disturbance of the uppermost aquifer.

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[This paper has not been peer-reviewed and has been semi-withdrawn by the authors due to errors they found in their data. They apparently plan to post a revised version and submit for peer-reviewed publication sometime in the future. It is likely that the "baseline" data on methane prevalence in water wells absent gas drilling, which shows an extremely low frequency of water wells with dangerous levels of methane, provided by industry sources, is credible.]

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EXHIBIT A

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EDUCATION

University of Notre Dame
B.S., Aerospace Engineering, *Magna Cum Laude*, June 1969.
Polytechnic Institute of New York
M.S., Civil Engineering, Grumman Masters Fellow, June 1971.
University of Colorado/Boulder
Ph.D., Civil Engineering, May 1977, University Fellow: 1974-1976.

AREAS OF EXPERTISE

Structural Engineering, Structural Mechanics, Computational and Experimental Fracture Mechanics, Microstructural Simulation of Fatigue and Fracture Mechanisms, Rock Mechanics, Numerical Methods, Engineering Education

PROFESSIONAL EXPERIENCE

June 1969 - June 1971
Grumman Aerospace Corporation. Bethpage, L.I., N.Y.
Rotating traineeship in the following areas: preliminary design on Navy F - 14; loads and dynamic studies, stress analysis, and final design on NASA Space Shuttle proposal. Two in- house technical publications.

July 1971 - June 1973
Peace Corps. Bejuma, Venezuela
County Engineer. Responsible for all technical services to a county of 40,000 people. Directed surveying, design, and construction of farmers' market, tourist hotel, and cemetery. Directed urban planning resource study. Co - directed urban renewal plan and data collection for section of state capital city.

September 1973 - August 1977
University of Colorado/Boulder
Department of Civil, Environmental and Architectural Engineering
Instructor for Courses:
Analytical Mechanics, Theoretical Fluid Mechanics
Teaching Assistant for Courses:
Mechanics of Materials
Materials Testing Laboratory
Research Assistant in Project: Constitutive Relations for Coal

September 1977 - June 1982
Cornell University, Department of Structural Engineering
Assistant Professor

September 1979 - July 1983
Cornell University, Department of Structural Engineering
Manager of Experimental Research

July 1982 - June 1987
Cornell University, Department of Structural Engineering
Associate Professor

August 1983 - August 1984
Lawrence Livermore National Laboratory Livermore, California
Visiting Research Engineer: Rock Fracture Simulation

January 1986 - September, 1986
Cornell University, Computer Aided Design Instructional Facility,
College of Engineering
Director

September 1986 - October, 1990
Cornell University, College of Engineering
Faculty Coordinator for Instructional Computing

July 1987 - Present
Cornell University, School of Civil and Environmental Engineering
Professor

September 1987 - April 1992
Cornell University, Program of Computer Graphics
Associate Director

September 1988 - Present
Fracture Analysis Consultants, Inc.
President

October 1990 - October 1994
Cornell University
Director, NSF-Synthesis National Engineering Education Coalition

July 1993 - Present
Cornell University
Dwight C. Baum Professor of Engineering

October 1994 - October 1995
Cornell University
Associate Director, NSF-Synthesis National Engineering Education Coalition

December 1997 –August 2005
Cornell Center for Theory and Simulation in Science and Engineering
Associate Director
Coordinator, Computational Materials Institute

July 1998 – December 1999
Cornell University
Coordinator, Infrastructure Group, School of Civil and Environmental Engineering

November 2002-Present
Cornell University
Member, Graduate Fields of Mechanical and Aerospace Engineering

May 2004-Present
Wright Patterson Air Force Base/AFRL/Air Vehicle Directorate/Structures Division
Structural Sciences Center of Excellence
Visiting Scientist

August 2005 – July 2007
Cornell University
Acting Director, Cornell Center for Theory and Simulation in Science and Engineering

November 2005 – Present
Cornell University
Weiss Presidential Fellow

July 2006 – December 2007
Cornell University
Coordinator, Infrastructure Group, School of Civil and Environmental Engineering

August 2005 – Present
Cornell University
Co-Editor in Chief, *Engineering Fracture Mechanics*

August 2010 – Present
Physicians, Scientists, and Engineers for Sustainable and Healthy Energy, Inc.
President

AWARDS AND HONORS

- **3 - M Corporation Scholarship,** 1965 - 1969
- **Grumman Masters Fellowship,** 1969 - 1971
- University of Colorado **Graduate Fellowships,** 1974 - 1976
- Cornell School of Civil Engineering **"Professor of the Year,"** 1977 - 78
- National Research Council/U.S. National Committee for Rock Mechanics **1978 Award for Outstanding Research in Rock Mechanics at the Doctoral Level**
- Cornell College of Engineering **"Professor of the Year,"** 1978 - 79
- Cornell School of Civil Engineering **"Professor of the Year,"** 1981 - 82
- **Presidential Young Investigator Award,** National Science Foundation, 1984 - 1989
- **Dean's Prize for Innovation in Teaching,** Cornell College of Engineering, 1989.
- **Dean's Prize for Innovation in Teaching,** Cornell College of Engineering, 1991.
- National Research Council/U. S. National Committee for Rock Mechanics **1991 Award for Applied Research** for the paper, "Simulation of Hydraulic Fracture Propagation in Poroelastic Rock with Applicaton to Stress Measurement Techniques", co-authored by Dr. T. J. Boone, *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.*, 28, 1, 1-14, 1991.
- International Association for Computer Methods and Advances in Geomechanics **1994 Significant Paper Award:** One of Five Significant Papers in the category of Computational/Analytical Applications in the past 20 years, "A Numerical Procedure for Simulation of Hydraulically-driven Fracture Propagation in Poroelastic Media", co-authored with T. J. Boone, *Int. J. Num. Analyt. Meth. in Geomech.*, 14, 1, 1990.
- **The NASA Group Achievement Award** for contributions, with former students Drs. Paul Wawrzynek and David Potyondy, to the Fuselage Structural Integrity Analysis Team, NASA Langley Research Center, 1996.
- **The First Society of Women Engineer's Professor of the Year Award,** Cornell College of Engineering, 1997.
- **J. P. and Mary Barger '50 Excellence in Teaching Award,** Cornell College of Engineering, 1997.
- **The MTS Visiting Professor Chair,** Department of Civil Engineering, University of Minnesota, May, 1998.
- **Aviation Safety Turning Goals into Reality Award,** NASA Airframe Structural Integrity Program Team, NASA Langley Research Center, with Dr. Paul Wawrzynek, 1999.
- **1999 Premier Award for Educational Software** for "Cracking Dams-HTTP://www.simscience.org", with Megann Polaha
- **Daniel Luzar '29 Excellence in Teaching Award,** Cornell College of Engineering, 2001.

- **Honor Award, University of Notre Dame,** College of Engineering, for "Significant Contributions to the Advancement of Engineering", 2002.
- **Weiss Presidential Teaching Fellow,** Cornell University, 2005.
- **George R. Irwin Medal,** American Society for Testing and Materials, 2006.
- **Richard J. Almeida Award, Project High Jump,** given each year to an individual whose dedication and contribution to High Jump have been extraordinary, 2008.
- **Fellow, International Congress on Fracture,** 2009, "For his pioneering contributions to the advanced computational simulation of fatigue and fracture processes leading to improved understanding for practical applications to integrity assessment of engineering structures".
- One of **TIME Magazine's "People That Mattered"** in 2011.

HONORARY/PROFESSIONAL SOCIETY MEMBERSHIP

Tau Beta Pi (1967 -
Chi Epsilon (1974 -
Sigma Xi (1977 -
American Academy of Mechanics (1988 -
American Society of Civil Engineers (Fellow, 1991)
  Chairman, Committee on Properties of Materials (1983 - 1985)
  Member, Committee on Finite Element Analysis of Reinforced Concrete
  Member, Committee on Computer Applications and Numerical Methods
International Society for Boundary Elements
International Society for Rock Mechanics
Society for Experimental Mechanics
American Society for Testing and Materials
  Committee E - 8 on Fracture and Fatigue
  Committee D - 18 on Soil and Rock for Engineering Purposes
  Committee C - 9 on Concrete
American Concrete Institute
  Committee 446 on Fracture Mechanics
RILEM
  Committee 90 - FMA on Fracture Mechanics Applications
  Member, Committee 89 - FMT on Fracture Mechanics Testing
American Rock Mechanics Association/Foundation
    Founding Member
    Member of the Board, 1999-2003

PROFESSIONAL REGISTRATION

Colorado	PE No. 14837
New York	PE No. 081309-0
Alaska	Professional Fishing Guide

UNITED STATES PATENT

Number 481,826, Hand - held, direct reading, fully mechanical fracture loading device for short-rod/bar specimens

PROFESSIONAL JOURNAL EDITORSHIPS AND ADVISORY BOARDS

Co-Editor-in-Chief:
Engineering Fracture Mechanics, August, 2005-present

Editorial Advisory Board:
International Journal for Numerical and Analytical Methods in Geomechanics
Boundary Element Communications
Engineering with Computers
Engineering Computations
International Journal for Multiscale Computational Engineering

PUBLICATIONS

TEXTS EDITED

1. **Fracture Mechanics of Concrete: Material Characterization and Testing**, co - edited with A. Carpinteri, Martinus Nijhoff Publishers, 1984.

PUBLISHED IN TEXTS

1. Ingraffea, A R (co - author). Modelling of Reinforcement and Representation of Bond. Chapter 3 in **Finite Element Analysis of Reinforced Concrete**, State - of - the - Art report prepared by the Task Committee on Finite Element Analysis of Reinforced Concrete Structures, Structural Division, ASCE, 1982, pp. 149- 203.

2. Ingraffea A R (co - author). Concrete Cracking. Chapter 4 in **Finite Element Analysis of Reinforced Concrete**. State-of-the-Art report prepared by the Task Committee on Finite Element Analysis of Reinforced Concrete Structures, Structural Division, ASCE, 1982, pp. 204 - 233.

3. Ingraffea A R. Numerical Modelling of Fracture Propagation. Chapter 4 in **Rock Fracture Mechanics**, H. P. Rossmanith, editor, CISM Courses and lectures No. 275, International Center for Mechanical Sciences, Udine, Italy, Springer - Verlag, Wien - New York, 1983, pp. 151 - 208.

4. Ingraffea A R, Saouma V. Numerical Modeling of Discrete Crack Propagation in Reinforced and Plain Concrete. Chapter 4 in **Application of Fracture Mechanics to Concrete Structures: Structural Application and Numerical Calculation**, G. C. Sih and A. DiTommaso, editors, Martinus Nijhoff Publishers, 1984.

5. Ingraffea A R, Gerstle W. Non - Linear Fracture Models for Discrete Crack Propagation. **Application of Fracture Mechanics to Cementitious Composites**, S. P. Shah, editor, Martinus Nijhoff Publishers, 1985, pp. 171 - 209.

6. Ingraffea A R. Fracture Propagation in Rock. Chapter 12 in **Mechanics of Geomaterials**, Z. P. Bazant, editor, John Wiley & Sons, Limited, 1985.

7. Ingraffea A R. Theory of Crack Initiation and Propagation in Rock. Chapter 3 in **Rock Fracture Mechanics**, B. Atkinson, editor, Academic Press, Inc., 1987.

8. Ingraffea A R, Gerstle W H, Perucchio R. Fracture Analysis with Interactive Computer Graphics. **Boundary Element Methods in Structural Analysis**, D. E. Beskos, Editor, ASCE, 1989, pp. 235 - 271.

9. Ingraffea A R, Sections 9.3, 12.3, 13.4, and 15.2, of **Fracture Mechanics of Concrete Structures: From Theory to Applications**, L. Elfgren, Editor, Chapman and Hall, London, 1989.

10. Ingraffea A R, Boone T J, Swenson D V. Computer Simulation of Fracture Processes. Chapter 22 in **Comprehensive Rock Engineering**, J. Hudson, Editor-in-Chief, Pergamon Press, Oxford, 1993.

11. Carter B J, Desroches J, Ingraffea A R, Wawrzynek P A. Simulating Fully 3D Hydraulic Fracturing. In **Modeling in Geomechanics**, Ed. Zaman, Booker, and Gioda, Wiley Publishers, pp 525-557, 2000.

I2. Ingraffea A R, Wawrzynek P A. Crack Propagation. In the **Encyclopedia of Materials: Science and Technology**, Elsevier Science, 2001.

13. Ingraffea A R, Wawrzynek P A. Finite Element Methods for Linear Elastic Fracture Mechanics. Chapter 3.1 in **Comprehensive Structural Integrity**, R. de Borst and H. Mang (eds), Elsevier Science Ltd., Oxford, England, 2003.

14. Ingraffea A R. Computational Fracture Mechanics. Volume 2, Chapter 11, **Encyclopedia of Computational Mechanics**, E. Stein, R. de Borst, T. Hughes (eds.) John Wiley and Sons, 2004, 2nd Edition 2008.

15. Emery J, Ingraffea A R. DDSim: Framework for Multiscale Structural Prognosis, Chapter 13 in **Computational Methods for Microstructure-Property Relationships**, S Ghosh and D Dimiduk (eds), Springer Science, 2011.

PUBLISHED IN JOURNALS

1. Ingraffea AR. Nodal Grafting for Crack Propagation Studies. *Int. J. Num. Meth. Eng.*, **11**, 7, 1977, 1185 - 1187.

2. Lynn PP, Ingraffea AR. Transition Element to be Used With Quarter - Point Crack Tip Elements. *Int. J. Num. Meth. Eng.*, **12**, 6, 1978, 1031 - 1036.

3. Ingraffea AR, Heuze FE. Finite Element Models for Rock Fracture Mechanics. *Int. J. Num. Analyt. Meth. Geomech.*, **4**, 1980, 25 - 43.

4. Ingraffea AR, Manu C. Stress - Intensity Factor Computation in Three Dimensions With Quarter - Point Elements. *Int. J. Num. Meth. Eng.*, **15**, 10, 1980, 1427 - 1445.

5. Blandford G, Ingraffea AR, Liggett JA. Two-Dimensional Stress Intensity Factor Calculations Using the Boundary Element Method. *Int. J. Num. Meth. Eng.*, **17**, 1981, 387 - 404.

6. Beech J, Ingraffea, AR. Three - Dimensional Finite Element Stress Intensity Factor Calibration of the Short Rod Specimen. *Int. J. Fracture*, **18**, 3, 1982, 217 - 229.

7. Perucchio R, Ingraffea AR, Abel JF. Interactive Computer Graphic Preprocessing for Three - Dimensional Finite Element Analysis. *Int. J. Num. Meth. Eng.*, **18**, 6, 1982, 909 - 926.

8. Saouma V, Ingraffea AR, Catalano D. Fracture Toughness of Concrete: K_{Ic} Revisited. *J. Eng. Mech. Div.*, ASCE, **108**, No. EM6, 1982, 1152 - 1166.

9. Perucchio R, Ingraffea AR. Interactive Computer Graphics Preprocessing for Three - Dimensional Boundary Integral Element Analysis. *J. Computers Structures*, **16**, 1 - 4, 1983, 153 - 166.

10. Ingraffea AR, Blandford G, Liggett JA. Automatic Modelling of Mixed - Mode Fatigue and Quasi - Static Crack Propagation Using the Boundary Element Method. *ASTM STP 791: Proc. of the 14th National Symposium on Fracture Mechanics*, June, 1983, I - 407 - I - 426.

11. Ingraffea AR, Gunsallus KL, Beech JF, Nelson PP. A Short - Rod Based System for Fracture Toughness Testing of Rock. *ASTM STP 855: Chevron - Notched Specimens: Testing and Stress Analysis*, 1984, 152 - 166.

12. Ingraffea AR, Perucchio R, Han T - Y, Gerstle WH, Huang YP. Three - Dimensional Finite and Boundary Element Calibration of the Short - Rod Specimen. *ASTM STP 855: Chevron-Notched Specimens: Testing and Stress Analysis*, 1984, 49 - 68.

13. Manu C, Ingraffea AR. Numerical Evaluation of the Growth Rate Material Parameters in Fatigue Propagation of Surface Flaws. *Nucl. Eng. Design*, 77, 2, March, 1984, 131 - 138.

14. Ingraffea AR, Gerstle W, Gergely P, Saouma V. Fracture Mechanics of Bond in Reinforced Concrete. *J. Structural Division*, ASCE, **110**, 4, 1984, 871 - 890.

15. Perucchio R, Ingraffea AR. An Integrated Boundary Element Analysis System with Interactive Computer Graphics for Three Dimensional Linear - Elastic Fracture Mechanics. *J. Comp. Structures*, **20**, 1985, 157 - 171.

16. Nelson PP, Ingraffea AR, O'Rourke TD. TBM Performance Prediction with Rock Fracture Parameters. *Int. J. Rock Mech. Mining Sciences*, **22**, 3, June, 1985, 189 - 192.

17. Elices M, Llorca J, Ingraffea AR. Fractura del Hormigon en Regimen Elastico y Lineal. Un Ejemplo: La Presa de Fontana (in Spanish), *Informes de la Construccion*. 37, 372, July, 1985, 19 - 33.

18. Ingraffea AR, Gerstle WH, Mettam K, Wawrzynek P, Hellier AK. Cracking of Welded Crane Runway Girders: Physical Testing and Computer Simulation. *Iron and Steel Engineer*, 62, 12, 1985, 46 - 52.

19. Boone TJ, Wawrzynek P, Ingraffea AR. Simulation of the Fracture Process in Rock with Application to Hydro-fracturing. *Int. J. Rock Mech. Mining Sciences*, 23, 3, 1986, 255 - 265.

20. Abel JF, Ingraffea AR, McGuire W, Greenberg DP. Interactive Color Graphical Postprocessing as a Unifying Influence in Numerical Analysis Research. *Finite Elements in Analysis and Design*, 2, 1986, 1 - 17.

21. Boone TJ, Wawrzynek P, Ingraffea, AR. Finite Element Modeling of Fracture Propagation in Orthotropic Materials. *Eng. Fract. Mech.*, 26, 2, 1987, 185 - 201.

22. Gerstle WH, Martha L, Ingraffea AR. Finite and Boundary Element Modeling of Crack Propagation in Two - and Three – Dimensions. *Eng. with Computers*. 2, 1987, 167 - 183.

23. Hellier AK, Sansalone M, Ingraffea AR, Carino NJ, Stone, C. Finite Element Analysis of the Pullout Test Using a Nonlinear Discrete Cracking Approach. *Cement, Concrete and Aggregates*, 9, 1, Summer 1987, 20 - 29.

24. Wawrzynek P, Ingraffea AR. Interactive Finite Element Analysis of Fracture Processes: An Integrated Approach. *Theor. Appld. Fract. Mech.* 8, 1987, 137 - 150.

25. Wawrzynek P, Ingraffea AR. An Edge - Based Data Structure for Two-Dimensional Finite Element Analysis. *Eng. with Computers*, 3, 1987, 13 - 20.

26. Llorca J, Elices M, Ingraffea AR. Analisis Lineal Y No Lineal De Propagacion De Fisuras En Hormigon," (In Spanish), *Revista Internacional de Metodos Numericos para Calculo y Diseno en Ingenieria*, 3, 3, 1987, 309 - 333.

27. Swenson DV, Ingraffea AR. Using Combined Experiments and Analysis to Generate Dynamic Critical Stress Intensity Data. *ASTM STP 969: Fracture Mechanics: 19th Symposium*, T. A. Cruse, Ed., American Society for Testing and Materials, Phila., 1988, 405 - 426.

28. Gerstle WH, Ingraffea AR, Perucchio R. Three-Dimensional Fatigue Crack Propagation Analysis Using the Boundary Element Method. *Int.J. Fatigue*, 10, 3, 1988, 187 - 192.

29. Swenson DV, Ingraffea AR. Modelling Mixed-Mode Dynamic Crack Propagation Using Finite Elements: Theory and Applications. *Computational Mech.*, 3, 1988, 187-192.

30. Linsbauer HN, Ingraffea AR, Rossmanith H P, Wawrzynek PA. Simulation of Cracking in a Large Arch Dam: Part I. *J. Structural Eng.*, 115, 7, July 1989, 1599 - 1615.

31. Linsbauer HN, Ingraffea AR, Rossmanith HP, Wawrzynek PA. Simulation of Cracking in a Large Arch Dam: Part II. *J. Structural Eng.*, 115, 7, July, 1989, 1616 - 1630.

32. Ingraffea AR. Case Studies of Simulation of Fracture in Concrete Dams. *Eng. Fracture Mech.*, 35, 1/2/3, 1990, 553-564.

33. Vossoughi H, Soudki K, White RN, Ingraffea AR, Sansalone M. Fatigue of Thick Steel Plates Bent to a Low R/t Ratio. *J. Pressure Vessel Tech.*, 111, August 1989, 259 - 265.

34. Boone TJ, Ingraffea AR. A Numerical Procedure for Simulation of Hydraulically - Driven Fracture Propagation in Poroelastic Media. *Int. J. Num. Analyt. Meth. Geomech.*, 14, 1990, 27-47.

35. Grigoriu M, Saif M, El Borgi S, Ingraffea AR. Mixed - Mode Fracture Initiation and Trajectory Prediction Under Random Stresses. *Int. J. Fracture*, 45, 1990, 19-34.

36. Boone TJ, Ingraffea AR, Roegiers J - C. Visualization of Hydraulically - Driven Fracture Propagation in Poroelastic Media Using a Super – Workstation. *J. Petroleum Tech*, June 1989, 574 - 580.

37. Wawrzynek PA, Ingraffea AR. An Interactive Approach to Local Remeshing Around a Propagating Crack. *Finite Elem. in Analys. and Design*, 5, 1989, 87 - 96.

38. Ingraffea AR, Barry A. Analytical Study of Transmission, Distribution Lines under Railroads. *Pipe Line Industry*, October 1989, 34 - 39.

39. Gray LJ, Martha LF, Ingraffea AR. Hypersingular Integrals in Boundary Element Fracture Analysis. *Int. J. Num. Meth. Eng.*, 29, 1990, 1135-1158.

40. Mann KA, Bartel DL, Wright TM, Ingraffea AR. Mechanical Characteristics of the Stem-Cement Interface. *J. Ortho. Research*, 9, 798-808, 1991.

41. Heuze F, Shaffer RJ, Ingraffea AR, Nilson RH. Propagation of Fluid-driven fractures in Jointed Rock. Part 1 - Development and Validation of Methods of Analysis. *Int. J. Rock Mech. Mining Sci. & Geomech. Abstr.*, 27, 4, 243 - 254, 1990.

42. Swenson DV, Ingraffea AR. The Collapse of the Schoharie Creek Bridge: A Case Study in Concrete Fracture Mechanics. *Int. J. Fracture*, 51, 73-92, 1991.

43. Gerstle WH, Ingraffea AR. Does Bond-Slip Exist? *Concrete International*, 13, 1, 44-48, 1991.

44. Gerstle WH, Ingraffea AR. Compliance and Stress-Intensity Factor Calibration of the CENRBB Specimen. *Int. J. Rock Mech. Mining Sci. & Geomech. Abstr.*, 28, 1, 85-92, 1991.

45. Bittencourt TN, Barry A, Ingraffea AR. Comparison of Mixed-Mode Stress Intensity Factors Obtained Through Displacement Correlation, J-Integral Formulation, and Modified Crack-Closure Integral. *ASTM STP 1131: Fracture Mechanics: Twenty Second Symposium (Vol. II)*, Philadelphia, 69-82, 1992.

46. Boone TJ, Ingraffea AR, Roegiers JC. Simulation of Hydraulic Fracture Propagation in Poroelastic Rock with Application to Stress Measurement Techniques. *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.*, 28, 1, 1-14, 1991.

47. Mukherjee Y X, Xie Z, Ingraffea AR. Delamination Buckling of Laminated Plates. *Int. J. Num. Meth. Eng.*, 32, 1321-1337, 1991.

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49. Martha LF, Gray, L J, Ingraffea AR. Three-Dimensional Fracture Simulation with a Single-Domain, Direct Boundary Element Formulation. *Int. J. Num. Meth. Eng.*, 35, 1992.

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51. Lutz E, Ingraffea AR, Gray L. Use of 'Simple Solutions' for Boundary Integral Methods in Elasticity and Fracture Analysis. *Int. J. Num. Meth. Eng.*, 35, 1737-1751, 1992.

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53. Martha L, Wawrzynek P, Ingraffea AR. Arbitrary Crack Propagation Using Solid Modeling. *Engrg. with Computers*, 9, 2, 63-82, 1993.

54. Sousa J, Carter B, Ingraffea AR. Numerical Simulation of 3D Hydraulic Fracture Using Newtonian and Power-Law Fluids. *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.*, 30, 7, 1265-1271, 1993.

55. Elbert K, Wright T, Rimnac C, Klein R, Ingraffea AR, Gunsallus K, Bartel D. Fatigue Crack Propagation Behavior of Ultra High Molecular Weight Polyethelene under Mixed Mode Conditions", *J. Biomedical Materials Research, 28*, 181-187, 1994.

56. Gray L, Potyondy D, Lutz E, Wawrzynek P, Martha L, Ingraffea AR. Crack Propagation Modeling. *Math. Models Meth. Applied Sci.*, 4, 2, 179-202, 1994.

57. Potyondy D, Wawrzynek P, Ingraffea AR. Discrete Crack Growth Analysis Methodology for Through Cracks in Pressurized Fuselage Structures. *Int. J. Num. Methods Eng.*, 38, 1611-1633, 1995.

58. Potyondy D, Wawrzynek P, Ingraffea AR. An Algorithm to Generate Quadrilateral or Triangular Element Surface Meshes in Arbitrary Domains with Applications to Crack Propagation. *Int. J. Num. Methods Eng.*, 38, 2677-2701, 1995.

59. Bittencourt T, Wawrzynek P, Sousa J, Ingraffea, AR. Quasi-Automatic Simulation of Crack Propagation for 2D LEFM Problems. *Eng. Fract. Mech.*, 55, 2, 321-334, 1996.

60. Bittencourt T, Ingraffea AR. Three-Dimensional Cohesive Crack Analysis of Short-Rod Specimens. *ASTM-STP 1220: Fracture Mechanics: 25th Volume*, 46-60, 1995.

61. Bittencourt T, Ingraffea AR. Um Metodo Numericao para o Modelmento de Fraturamento Coesivo em 3D (In Portugese). *Revista Internacional de Metodos Numericos para Calculo y Diseno en Ingeneria*, 11, 4, 1-10, 1995.

62. Zehnder A, Ingraffea AR. Reinforcing Effects of Coverlayers on the Fatigue Life of Copper-Kapton Flex Cables. *IEEE Trans. Comp. Pack. Manuf. Tech.*, 18:704-710, 1995.

63. Shah KR, Carter BJ, Ingraffea AR. Hydraulic Fracturing Simulation in Parallel Computing Environment. *Int. J. Rock Mech. & Min. Sci.*, 34, 3-4, Paper 282, 1997.

64. Chen C-S, Wawrzynek PA, Ingraffea AR. Methodology for Fatigue Crack Growth and Residual Strength Prediction with Applications to Aircraft Fuselages. *Computational Mechanics*, 19:527-532, 1997.

65. Hanson JH, Ingraffea AR. Standards for Fracture Toughness Testing of Rock and Manufactured Ceramics: What Can We Learn for Concrete? *Cement, Concrete and Aggregates*, 19:79-87, 1997.

66. Riddell WT, Ingraffea AR, Warwrzynek PA. Experimental Observations and Numerical Predictions of Three-Dimensional Fatigue Crack Propagation. *Eng. Fract. Mech.*, 58: 293-310, 1997.

67. Singh R, Carter B, Wawrzynek P, Ingraffea AR. Universal Crack Closure Integral for SIF Estimation. *Eng. Fract. Mech.*, 60:133-146, 1998.

68. Hwang CG, Wawrzynek P, Tayebi AK, Ingraffea AR. On the Virtual Crack Extension Method for Calculation of the Rates of Energy Release Rate. *Eng. Fract. Mech.*, 59:521-542, 1998.

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70. Carter BJ, Wawrzynek, PA, Ingraffea AR. Automated 3D Crack Growth Simulation. Gallagher Special Issue of *Int. J. Num. Methods Eng.*, 47:229-253, 2000.

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72. Castell M, Ingraffea AR, Irwin L. Fatigue Crack Growth in Pavements. 126:283-290, *ASCE J. Transportation Eng.*, 2000.

73. TerMaath SC, Ingraffea AR, Wawrzynek PA. A Computational Fracture Mechanics Approach for the Analysis of Facesheet-from-Core Disbond of Honeycomb Core Sandwich Panels. *Fatigue and Fracture Mechanics: 30th Volume, STP 1360*, P.C. Paris and K.L. Jerina, Eds., American Society for Testing and Materials, West Conshohocken, PA, 169-182, 1999.

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26. Sabouni, A. - R., Loizias, M., Sutharshana, S., Ingraffea, A. R., "Finite Element Analysis of a Reinforced Concrete Beam, "Department of Structural Engineering Research Report 82 - 17, School of Civil and Environmental Engineering, Cornell University, March, 1986, 51 pp.

27. Sabouni, A. - R., Elzanaty, A., Ingraffea, A. R., "Finite Element Idealization of Mixed - Mode Fracture," Department of Structural Engineering Research Report 83 - 9, School of Civil and Environmental Engineering, Cornell University, March 1986, 58 pp.

28. Ingraffea, A. R., McGuire, W., Pekoz, T., Gerstle, W., Mettam, K., Wawrzynek, P., Hellier, A., Final Report, Volume 1 of 2. Task IV, Document 86 - 1, AISE/Cornell University Crane Runway Girder Project, June 23, 1986, 47 pp.

29. Mettam, K., Ingraffea, A. R., Gerstle, W. H., "A Bibliography on Fatigue in Crane Runway Girders," Task I, Report No. 1, in Final Report - Appendices, Volume 2 of 2. Document 86 - 1, AISE/Cornell University Crane Runway Girder Project, June 23, 1986, 22 pp.

30. Gerstle, W. H., Ingraffea, A. R., "Numerical Modelling of Forces Transmitted to the Web - to - Flange Junction of Crane Runway Girders Due to Wheel Loads," Task II, Report No. 1, in Final Report - Appendices. Volume 2 of 2. Document 86 - 1, AISE/Cornell University Crane Runway Girder Project, June 23, 1986, 108 pp.

31. Ingraffea, A. R., Lin, S. C., "Effects of Elastomeric Rail Pad on Forces Transmitted to the Web - to - Flange Junction of Crane Runway Girders," Task II, Report No. 2, in Final Report - Appendices, Volume 2 of 2. Document 86 - 1, AISE/Cornell University Crane Runway Girder Project, June 23, 1986, 46 pp.

32. Wawrzynek, P., Ingraffea, A. R., "The Effect of Stiffeners on the Forces Transmitted to the Web - to - Flange Junction of Crane Runway Girders," Task II, Report No. 3, in Final Report - Appendices. Volume 2 of 2. Document 86 - 1, AISE/Cornell University Crane Runway Girder Project, June 23, 1986, 49 pp.

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34. Blewitt, J. R., Ingraffea, A. R., O'Rourke, T. D., Stewart, H. E., "Analytical Study of Stresses in Transmission and Distribution Pipelines Beneath Railroads," Topical Report GRI - 87/0234. Gas Research Institute, Chicago, IL, 1987, 156 pp.

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38. Sansalone, M., Ingraffea, A. R. and Soudki, K., "Fatigue Behavior of Steel Plates Bent to a Low R/t Ratio (Phase III)", Department of Structural Engineering Research Report 89 - 7, School of Civil and Environmental Engineering, Cornell University, June 1989, 134 pp.

39. Gray, L. J., Martha, L. F., Ingraffea, A. R., "Hypersingular Integrals in Boundary Element Fracture Analysis," BSC 89/6, IBM Bergen Scientific Center, Bergen, Norway, March, 1989, 23 pp.

40. Boone, T. and Ingraffea, A. R., "Simulation and Visualization of Hydraulic Fracture Propagation in Poroelastic Rock," Department of Structural Engineering Research Report 89 - 6, School of Civil and Environmental Engineering, Cornell University, June, 1989, 430 pp.

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42. Swenson, D. V., Ingraffea, A. R., "The Collapse of the Schoharie Creek Bridge: A Case Study in Concrete Fracture Mechanics", Department of Structural Engineering Research Report 90-4, School of Civil and Environmental Engineering, Cornell University, April, 1990, 39 pp.

43. Ingraffea, A., Grigoriu, M., "A Validation of Predictive Capability", Department of Structural Engineering Research Report 90 - 8, School of Civil and Environmental Engineering, Cornell University, August, 1990.

44. Wawrzynek, Paul A., Ingraffea, A. R., "Discrete Modeling of Crack Propagation: Theoretical Aspects and Implementation Issues in Two and Three Dimensions", Department of Structural Engineering Research Report 91-5, School of Civil and Environmental Engineering, Cornell University, August, 1991, 211 pp.

45. Lutz, E., Ingraffea, A. R., "Numerical Methods for Hypersingular and Near-Singular Boundary Integrals in Fracture Mechanics", Department of Structural Engineering Research Report 91-6, School of Civil and Environmental Engineering, Cornell University, August, 1991, 223 pp.

46. Sousa, J., Ingraffea, A. R., "Three-Dimensional Simulation of Near-Wellbore Phenomena Related to Hydraulic Fracturing from a Perforated Wellbore", Department of Structural Engineering Research Report 92-5, School of Civil and Environmental Engineering, Cornell University, May, 1992, 269 pp.

47. Bittencourt, T., Ingraffea, A. R., "Computer Simulation of Linear and Nonlinear Crack Propagation in Cementitious Materials," Department of Structural Engineering Research Report 93-3, School of Civil and Environmental Engineering, Cornell University, May, 1993, 303 pp.

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49. P. Wawrzynek, Ingraffea, A., "FRANC2D: A Two-Dimensional Crack Propagation Simulator Version 2.7 User's Guide", NASA Contractor Report 4572, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, March, 1994, 59 pp.

50. "Fracture Mechanics Life Analytical Methods Verification Testing-Final Report", NAS8-38103, for the George C. Marshall Space Flight Center, NASA, Nichols Research Corporation/Cornell University/ Fracture Analysis Consultants, Inc., 1994.

51. Chi, W-M, Dierlein, G., Ingraffea, A. R., "Finite Element Fracture Mechanics Investigation of Welded Beam-Column Connections", SAC Joint Venture/CUREe Subcontract 26-28, Structural Engineering Report No. 97-7, Cornell University, Ithaca, NY, 167 pp.

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53. Hwang, C., Ingraffea, A. R., Wawrzynek, P., "Virtual Crack Extension Method for Calculating Rates of Energy Release Rate and Numerical Simulation of Crack Growth in Two and Three Dimensions", Structural Engineering Research Report 99-2, School of Civil and Environmental Engineering, Cornell University January, 1999.

54. Hanson, J. H., Ingraffea, A. R., "Proposed Standard Test Method for Round Double Beam Fracture Toughness of Concrete," *Research Report*, 00-1, Department of Structural Engineering, Cornell University, Ithaca, NY, Jan. 2000.

55. Chen, CS, Wawrzynek, PA, and Ingraffea, AR. "Finite Element Stress Analysis Subroutines for RAPID", Final Report to Federal Aviation Administration, Project DTFA0300C00002, 2000.

56. Lewicki, DG, Spievak, L, Wawrzynek, PA, Ingraffea, AR, Handshuh, R, "Consideration of Moving Tooth Load in Gear Crack Propagation Predictions", NASA/TM-2000-210227, ARL-TR-2246, DETC2000/PTG-14386, July, 2000.

57. Iesulauro E, Ingraffea AR. "Computational Micro-Mechanical Investigations of Crack Initiation in Metallic Polycrystals", NASA Langley Research Center, Final Report on Project NAG-1-0205, July 21, 2006, 210 pages.

58. Ingraffea AR, Tuegel E. "Structural Life Forecasting in Extreme Environments", Structural Sciences Center, AFRL/RBSM, Wright Patterson AFB, Dayton, Ohio, October, 2009.

FUNDED RESEARCH PROJECTS

Structural Engineering

1. "An Investigation into Mixed - Mode Fracture Propagation in Rock," National Science Foundation Research Initiation Grant ENG78 - 05402, 4/78 - 3/80, $25,000, Principal Investigator.

2. "Finite Element Analysis of Reinforced Concrete for Cyclic Loading," National Science Foundation Grant PFR - 7900711, 4/79-3/81, $84,000, Principal Investigator. P. Gergely and R. N. White, Co - Principal Investigators.

3. "Laboratory Testing of the Crack - at - an - Interface Problem," Sandia National Laboratories Contract No. 13 - 5038, 5/79 - 5/80, $42,000, Principal Investigator.

4. "Three - Dimensional Interactive Computer Graphics in Structural and Geo - Mechanics," National Science Foundation Grant CME79 - 16818, 1/80 - 6/82, $500,000, Faculty Investigator. J. F. Abel, D. P. Greenberg, W. McGuire, Co-Principal Investigators; F. H. Kulhawy, Faculty Investigator.

5. "Interaction Between Steel and Concrete for Earthquake-Type Loadings," National Science Foundation Grant CME80 - 20925, 4/1/81 - 9/30/83, $140,000, Principal Investigator. P. Gergely, Co - Principal Investigator.

6. "Interactive Color Display of Three - Dimensional Engineering Analysis Results," National Aeronautics and Space Administration, Grant NAG3 - 395, 3/1/83 - 2/28/87, $133,285, Associate Investigator. J. F. Abel, Principal Investigator.

7. "Welded Crane Runway Girder Study," Association of Iron and Steel Engineers, 8/83 - 8/85, $234,348, Principal Investigator. W. McGuire, T. Pekoz, Co - Principal Investigators.

8. Presidential Young Investigator Award in Structural Mechanics, National Science Foundation Grant 8351914, 6/84 - 6/89, $500,000, Principal Investigator.

9. "Fatigue Behavior of Thick Steel Plates," Electric Boat Division/General Dynamics, PO# R2041 - 907, 1/86 - 12/88, $233,218, Co - Principal Investigator. R. N. White, Principal Investigator.

10. "Probabilistic Fracture Mechanics," AFOSR, 4/87 - 4/90, $269,624, Co - Principal Investigator. M. Grigoriu, Co - Principal Investigator.

11. "CISE Research Instrumentation: Computer Graphics Dynamic Simulation for Scientific Inquiry," National Science Foundation Grant CCR - 8717024, 4/1/88 - 9/30/89, $145,600, Co - Principal Investigator. M. Cohen, D. Greenberg, and J. Abel, Co - Principal Investigators.

12. "Visualization for Supercomputing: A Graphics Workstation Approach," National Science Foundation, Grant ASC - 8715478, 8/1/88 - 1/31/90, $202,532, Co - Principal Investigator. D. Greenberg, Principal Investigator. J. Abel, M. Cohen, D. Caughey, Co - Principal Investigators.

13. "Advanced Computational Fracture Mechanics," Digital Equipment Corporation, 7/89 - 7/90, $100,000, Principal Investigator.

14. "Fatigue and Damage Tolerance", Northrop-Grumman Corporation, 6/89-12/00, $249,000, Principal Investigator.

15. "Research in Fracture Mechanics", Exxon Education Foundation, 9/89-9/92, $30,000, Principal Investigator.

16. "Crack Growth Prediction Methodology for Multi-Site Damage", NASA Langley Research Center, 9/90-9/98, $926,147, Principal Investigator.

17. "Fracture Mechanics Life Analytical Methods Verification Testing", Nichols Research Corp. /NASA MSFC, 8/91 - 8/94, $183,860, Principal Investigator.

18. "Mode I/III Fatigue Crack Growth Measurements in 2024 Aluminum Sheet", NASA Langley Research Center, 6/91-9/93, $159,836, Co-Principal Investigator. A. Zehnder, Co-Principal Investigator.

19. "A Study of Failure Mechanisms of Advanced Flex Cables", IBM Corporation, 1/20/92-1/19/93, $25,000, Co-Principal Investigator. A. Zehnder, Co-Principal Investigator.

20. "Detecting Cracks in Concrete Dams", U. S. Army Engineer Waterways Experiment Station, 4/1/94-1/1/95, $39,339, Co-Principal Investigator. M. Sansalone, Principal Investigator.

21. "Measurement of Fracture Toughness of Concrete Using the Short-Rod Procedure", NSF CMS 9414243, 9/95-8/98, $203,854. Principal Investigator.

22. "Simulation of Damage Tolerance in Honeycomb Core Structure", Boeing Commercial Airplane Co., 5/96-12/98, $204,000. Principal Investigator.

23. "Simulation of Crack Growth in Spiral Bevel Gears", NASA Glenn Research Center, 12/96-12/00, $289,961. Principal Investigator.

24. "Fracture of Steel Joints", CUREe SAC Phase II Subcontract No. 28, 9/96-12/96, $23,000. Co-Principal Investigator. Prof. G. Deierlein, Principal Investigator.

25. "Multidisciplinary Center for Earthquake Engineering Research", NSF, 10/97-9/02, $1,500,000. Associate Investigator. Prof. R. White, Co-Principal Investigator; Profs. G. Deierlein, M, Grigoriu, Associate Investigators.

26. "Simulation of Crack Propagation on Teraflop Computers", NSF, 1/98-12/00, $1,800,000. Co-Principal Investigator. Profs. S. Vavasis and K. Pingali, Co-Principal Investigators.

27. "Probabilistic Simulation of Fatigue Crack Initiation", AFOSR, 3/98-2/01, $600,000. Principal Investigator. Profs. M. Grigoriu, M. Miller, P. Dawson, Co-Principal Investigators.

28. "Development and Implementation of T-Stress Criterion", NASA Langley Research Center, 8/97-3/98, $20,128. Principal Investigator.

29. "Crack Turning and Arrest Mechanisms for Integral Structures", NASA Langley Research Center, 1/98-6/00, $103,642. Principal Investigator.

30. "Basic Research in Crack Growth Prediction Methodologies", NASA Langley Research Center, 1/98-11/99, $185,000. Principal Investigator.

31. "Fatigue Crack Growth in Aluminum Alloys", Alcoa Foundation, 6/975/98, $10,000. Principal Investigator.

32. "Multiscale Modeling of Defects in Solids", NSF 9873214, 10/98-9/01, $1,500,000. Co-Principal Investigator. Profs. P. Dawson, and J. Sethna Co-Principal Investigators, C. Myers, Co-Principal Investigator.

33. "A Two-Tier Computation and Visualization Facility for Multiscale Problems", NSF 9972853, 10/99-9/04, $1,500,000. Co-Principal Investigator. Profs. K. Pingali, N. Chrisochoides, C. Cruz-Neira, Guang Gao, Co-Principal Investigators.

34. "Finite Element Stress Analysis Subroutines for RAPID", Federal Aviation Administration, 9/99-4/2000, $34,438. Principal Investigator.

35. "Finite Element/Fracture Mechanics Simulation of Trajectories During Slitting of Plastic Films", Eastman Kodak Company, 1/1/99-12/31/01, $110,000. Principal Investigator.

36. "ITR: Adaptive Software for Field-driven Simulations", NSF 0085969, 9/1/00-8/31/04, $5,000,000. Co-Principal Investigator. Prof. K. Pingali, PI, B. K. Soni, J. F. Thompson S. A. Vavasis, Co-PIs.

37. "Developing Technologies for Modeling Damage in Stiffened Thin Shell Structures", NASA LaRC, 11/1/01-10/31/04, $160,107. Principal Investigator.

38. "Computational Micro-Mechanical Investigations of Crack Initiation in Metallic Polycrystals", NASA LaRC, 2/1/02-1/31/05, $230,182. Principal Investigator.

39. "The Institute for Future Space Transport", NASA Marshall RC University Research, Engineering and Technology Institute, 8/1/02-9/15/07, $15,616,120, Co-Principal Investigator. W. Shyy, Principal Investigator, B. Soni, B. Davidson, J. Olds, Co-Principal Investigators.

40. "Structural Integrity Prognosis System-SIPS", DARPA, 10/1/03-8/31/08, $1,288,400, Cornell Principal Investigator. J. Madsen, Northrop Grumman Corp. Project Manager.

41. "Fracture Mechanics Analysis of MANPADS-Damaged Aircraft Structures", NASA LaRC, 5/05-9/06, $74,000. Principal Investigator.

42. "Advanced Digital Material Machine (ADMM) "AFOSR/DURIP, 2006, $300,000. Principal Investigator.

43. "Multi-Scale Simulation of Cracking Processes in Metallic Materials", NASA LaRC, NNX07AB69A, 1/07-12/10, $392,526. Principal Investigator.

44. "Constellation University Institute Project: Computational Simulation of Damage Tolerance for Composite and Metallic Structures", NASA, 10/1/07-9/30/10, $450,000, Principal Investigator.

45. "Multi-scale Simulation of Fatigue Damage", Northrop Grumman Corporation, 1/1/07-12/31/09, $55,000, Principal Investigator.

46. "Computational Methods in Physics-Based Modeling of Damaged Flight Structures", NASA LaRC NNX08AC50A, 1/1/08-12/31/2010, $299,972, Principal Investigator.

47. "Collaboration between Cornell Fracture Group and Exponent, Inc.", Exponent Inc., 3/08-12/08, $29,204, Principal Investigator.

48. "Geometrical Simulation of Complete Process of Microstructurally Small Fatigue Cracking" E DARPA, HR0011-09-1-0002, 1/09-12/09, $150,000, Principal Investigator.

49. "Parallel File Serving R&D", IBM, $20,200, 7/09-6/10, Principal Investigator.

50. "Prognosis of Long-Term Load-Bearing Capability in Aerospace Structures: Quantification of Microstructurally Short Crack Growth", Air Force Office of Scientific Research, $750,000, 5/10/5/13, Co-Principal Investigator.

Geotechnical Engineering

1. "TBM Performance Study," U.S. Dept. of Transportation, 3/80 - 3/82, $164,000, Associate Investigator. T. D. O'Rourke, Principal Investigator; F. H. Kulhawy, Associate Investigator.

2. "A Study of Cast Iron Gas Main Replacement," New York Gas Group, 8/81 - 12/83, $287,000, Associate Investigator. T. D. O'Rourke, Principal Investigator; F. H. Kulhawy, Associate Investigator.

3. "Uplift/Compression Transmission Line Structure Foundation Research," Electric Power Research Institute, RP1493 - 4, 1984 - 1988, $2,450,000, Associate Investigator. F. H. Kulhawy, Principal Investigator; T. D. O'Rourke, M. Grigoriu, Associate Investigators.

4. "Numerical Investigations into Crack Propagation in Rock," National Science Foundation Grant CEE - 8316730, 6/1/84 - 5/30/86, $150,000. Principal Investigator

5. "Workshop on Interactive Computer Modeling and Graphics for the Design and Optimization of Field and Laboratory Experiments in Geotechnical Engineering." National Science Foundation Grant CEE 8413471, 12/84 - 11/86, $39,681. Principal Investigator.

6. "Evaluation of Cased and Uncased Gas Distribution and Transmission Piping Under Railroads and Highways, Gas Research Institute, 11/86 - 1/94, $ 3,602,035. Co-Principal Investigator. T. D. O'Rourke and H. Stewart, Co-Principal Investigators.

7. "Influence of Perforations Upon Subsequent Hydraulic Fracturing," Digital Equipment Corp. and Dowell Schlumberger, 1/88 - 12/96, $448,000. Principal Investigator.

8. "Computational Simulation of Hydrofracturing", NSF CISE Postdoctoral Associate Award for Dr. K. Shah. 11/95-10/97, $46,200. Principal Investigator.

9. "3D Crack Initiation and Propagation in Transparent Rock Like Materials Loaded in Compression", NSF, 9/96-8/99, $148,000. Principal Investigator.

Engineering Education

1. "Study of Complementary Research and Teaching in Engineering Science - PROJECT SOCRATES," U. S. Department of Education, Fund for the Improvement of Post - Secondary Education, G 008642170, 9/15/86 - 9/14/89, $236,496, Project Director.

2. "Workstations For Instructional Computing in the College of Engineering," Digital Equipment Corporation, 5/1/88 - 4/31/90, $664,000. Project Director.

3. "Workstations for Project SOCRATES," Apollo Computer, Inc., June, 1989, $87,105. Project Director.

4. "Workstations for Project SOCRATES", Sun Microsystems, Inc., June, 1990, $89,415. Project Director.

5. "Synthesis National Engineering Education Coalition", National Science Foundation, 9/30/90 - 9/30/94, $12,278,036. Project Director.

6. "1992 Summer Institute for Computer Graphics", New York State Education Department, $56,000, 7/19/92-8/8/92, Project Co-Director. C. Mink, Director.

7. "Support for Educational Computing Equipment", Hewlett Packard, 6/92, $427,318. Project Director.

8. "Synthesis Coalition/GE Foundation Faculty Exchange Award", GE Foundation, Spring 1994 - Spring 1997, $230,000, Principal Investigator.

9. "Synthesis Coalition/Raytheon Company Student Award" Raytheon Company, 1994-1995, $24,000, Principal Investigator.

10. "Application and Infrastructure Linkage to Altoona Area School District and Manhatten Center for Science and Math High School", Synthesis Coalition/NSF/GE Foundation/Mr. A. Misciagna, 10/1/94-9/30/96, $284,000, Project Director.

11. "Integration of Information Age Networking and Parallel Supercomputer Simulations into University and General Science K-12 Curricula", NSF, 1/96-12/98, $102,000, Co-Principal Investigator. J. Sethna, Co-Principal Investigator.

12. REU Supplement to "Measurement of Fracture Toughness of Concrete Using the Short-Rod Procedure", NSF, 9/95-9/98, $10,000, Principal Investigator.

13. REU Supplements to "Integration of Information Age Networking and Parallel Supercomputer Simulations into University and General Science K-12 Curricula", NSF, 9/96-9/98, $20,000, Co-Principal Investigator with Prof. James Sethna, Physics.

14. "Tech City Exhibition", NSF, 7/98-6/01, $639,543, Co-Principal Investigator. Dr. C. Trautmann, Principal Investigator.

15. "An Advanced Interactive Discovery Environment for Engineering Education" NASA/New York State/AT&T, 2/1/01-12/31/07, $4,300,000, Co-Principal Investigator. Prof. B. Davidson, Principal Investigator, Prof. E. Liddy, Co-PI.

16. "An IGERT Training Program In Sustainable Energy Recovery From The Earth-Education At The Intersection Of Geosciences And Engineering". July 2010-June 2015, National Science Foundation, $1,137,047. Co-Principal Investigator. Prof. Jeff Tester, Principal Investigator, Profs. Terry Jordan, Paulette Clancy, Co-PI's.

Co-operative Research

1. "Co-operative Agreement between Cornell University and the Technical University of Delft", National Science Foundation Grant PFR-8020924, 1/81 - 12/82, $25,800, Co - Principal Investigator. P. Gergely, Principal Investigator; R. N. White, Co – Principal Investigator.

2. "Scientific Visit to Plan Co-operative Research in Hydraulic Fracturing," Catholic University of Rio de Janiero/Cornell University, National Science Foundation Grant INT - 8814466, July 1988, $2,336, Principal Investigator.

3. "Fracture Mechanics Case Studies of Concrete Dams" Technical University of Vienna, Austria/Cornell University, National Science Foundation Grant INT-8814457, 2/89 - 2/92, $8,080, Principal Investigator.

4. International Supplement to National Science Foundation Grant "ITR: Adaptive Software for Field-driven Simulations", to collaborate with Czech Technical University, Z. Bittnar, Czech Co-PI, 7/99-8/03, $24,375, Co-Principal Investigator.

THESES DIRECTED

Master of Science

1. "A Fracture Mechanics Analysis of the Fontana Dam," John Chappell, May, 1981.
2. "Mixed-Mode Crack Propagation in Mortar and Concrete." Manrique Arrea, January 1982.
3. "The Fracture Mechanics of Bond in Reinforced Concrete," Walter Gerstle. May 1982.
4. "Concrete Fracture: A Linear Elastic Fracture Mechanics Approach," David Catalano, August, 1982.
5. "Interactive and Graphic Two - Dimensional Fatigue Crack Propagation Analysis Using Boundary Element Method," Kodwo Otsei;du, January, 1983.
6. "An Experimental Investigation of Fatigue Cracking in Welded Crane Runway Girders Due to Wheel Induced Stresses," Kirk I. Mettam, January, 1986.
7. "An Investigation of the Failure Process of the STEM - PMMA Interface in Cemented Prostheses," Leonard Daniel - Timmie Topoleski, June 1986.
8. "Interactive Finite Element Analysis of Fracture Processes: An Integrated Approach," Paul A. Wawrzynek, May 1987.
9. "Analytical Study of Stresses in Transmission and Distribution Pipelines Beneath Railroads," J. Russell Blewitt, May 1987.
10. "Case Studies of Cracking of Concrete Dams--A Linear Elastic Approach," Shan - Wern Steve Lin, January 1988.
11. "Fracture Analysis Code: A Computer - Aided Teaching Tool," Maya Srinivasan, January 1988.
12. "Two-Dimensional Numerical Evaluation of Near Wellbore Phenomena: Perforation Performance & Interacting Hydraulic Fractures", Stephen James Lamkin, May 1990.
13. "On Finite Element Analysis of Face Sheet Cracking in Honeycomb Core Sandwich Panels", Kenneth Ferguson, January 1999.
14. "Simulating Fatigue Crack Growth in Spiral Bevel Gears", Lisa Eron Spievak, August 1999.
15. "Cracking Dams: An Interactive Web Site for K12", Megann V. Polaha, August 1999.
16. "Experimental Investigations into Damage Tolerance of Honeycomb Sandwich Panels", Ani Ural, August, 1999.
17. "Simulations of Crack Initiation in Aluminum Alloys with Inclusions", Ketan Dodhia, January 2002.
18. "Decohesion of Grain Boundaries in Statistical Representations of Aluminum Polycrystals", Erin Iesulauro, January, 2002.
19. "An Evaluation of Surface Cracks in Welded Components of Nuclear Reactor Vessels", John Emery, May, 2003.
20. "Microstructural Reconstruction and Three-Dimensional Mesh Generation for Polycrystalline 7075-T651 Aluminum Alloy", Michael Veilleux, May, 2007.
21. "A Two-Dimensional Multiscale Method for Fatigue Crack Nucleation in Polycrystalline Aluminum Alloys", Jeffrey Bozek, May, 2007.

Doctor of Philosophy

1. "Three-Dimensional Finite Element Analysis of Cyclic Fatigue Crack Growth of Multiple Surface Flaws." Corneliu Manu, June, 1980. Professor (Retired) University of Toronto.

2. "Automatic Two-Dimensional Quasi-Static and Fatigue Crack Propagation Using the Boundary Element Method." George E. Blandford, January, 1981. Professor, University of Kentucky.

3. "Interactive Finite Element Analysis of Reinforced Concrete: A Fracture Mechanics Approach," Victor E. Saouma, January, 1981. Professor, University of Colorado/Boulder.

4. "An Integrated Boundary Element Analysis System with Interactive Computer Graphics for Three- Dimensional Linear Elastic Fracture Mechanics," Renato S. Perucchio, January, 1984. Professor, University of Rochester.

5. "Finite and Boundary Element Modelling of Crack Propagation in Two- and Three - Dimensions Using Interactive Computer Graphics," Walter H. Gerstle, January, 1986. Professor, University of New Mexico.

6. "Modeling Mixed - Mode Dynamic Crack Propagation Using Finite Elements," Daniel V. Swenson, January 1986. Professor, Kansas State University.

7. "Simulation of Crack Propagation in Poroelastic Rock with Application to Hydrofracturing and *In - Situ* Stress Measurement," Thomas J. Boone, January, 1989. VP of Research, EXXON.

8. "Topological and Geometrical Modeling Approach to Numerical Discretization and Arbitrary Fracture Simulation in Three-Dimensions," Luiz Martha, August, 1989. Professor, Catholic University of Rio de Janeiro, Brazil.

9. "Numerical Methods for Hypersingular and Near-Singular Boundary Integrals in Fracture Mechanics", Earlin Lutz, May, 1991. Senior Research Engineer, Bentley, Inc.

10. "Discrete Modelling of Crack Propagation: Theoretical Aspects and Implementation Issues in Two and Three Dimensions", Paul A. Wawrzynek, August, 1991. Chief Engineer, Fracture Analysis Consultants, Inc.

11. "Three-Dimensional Simulation of Near-Wellbore Phenomena Related to Hydraulic Fracturing from a Perforated Wellbore", José Sousa, May, 1992. Professor, University of Campinas, Brazil.

12. "Computer Simulation of Linear and Nonlinear Crack Propagation in Cementitious Materials", Tulio Bittencourt, May, 1993. Professor, University of Sao Paulo, Brazil.

13. "A Methodology for Simulation of Curvilinear Crack Growth in Pressurized Shells", David Potyondy, August, 1993. Senior Research Engineer, Itasca, Inc.

14. "Experimental Validation Testing of Numerical Prediction Techniques for Three-Dimensional Fracture and Fatigue", William Riddell, June, 1995. Assoc. Professor, Rowan University.

15. "Crack Growth Simulation and Residual Strength Prediction in Thin Shell Structures", Chuin-Shan Chen, January, 1999. Assoc. Prof., National Taiwan University.

16. "Virtual Crack Extension Method for Calculating Rates of Energy Release Rate and Numerical Simulation of Crack Growth in Two and Three Dimensions", Changyu Hwang, January, 1999. Professor, Seoul University of Venture and Information.

17. "Crack Turning in Integrally Stiffened Aircraft Structures", Richard Pettit, August, 2000. Chief Engineer, FractureLab, LLC.

18. "An Experimental-Computational Evaluation of the Accuracy of Fracture Toughness Tests on Concrete", James Hanson, August, 2000. Assoc. Prof., Rose-Hulman Institute of Technology.

19. "Interface Modeling of Composite Material Degradation", Tong-Seok Han, May, 2001 (with Prof. Sarah Billington). Research Engineer, Korea Electric Power Research Institute.

20. "Modeling and Simulation of Fatigue Crack Growth in Metals Using LEFM and a Damage-Based Cohesive Model", Ani Ural, May, 2004 (with Prof. Katerina Papoulia). Assistant Professor, Villanova University.

21. "Decohesion of Grain Boundaries in Statistical Representations of Aluminum Polycrystals", Erin Iesulauro, May, 2006. Staff Engineer, Los Alamos National Laboratory.

22. "A Hierarchical, Probabilistic, Damage and Durability Simulation Methodology", John Emery, May, 2007, Staff Engineer, Sandia National Laboratory.

23. "Finite Element Simulation of Fatigue Crack Stages in AA 7075-T651 Microstructure", Jacob Hochhalter, May, 2010, Staff Engineer, NASA Langley Research Center.

24. "Geometrically explicit finite element modeling of AA7075-T651 microstructure with fatigue cracks", Michael Veilleux, August, 2010, Senior Member of Technical Staff, Sandia Livermore National Laboratory.

25. "A Multiscale Method for Fatigue Crack Propagation in Aluminum Alloys", Jeffrey Bozek, December, 2012 (expected).

26. "Microstructural Simulation of Fracture Processes in Cortical Bone", Erin Oneida, December, 2012 (expected).

27. "Residual Strength of Damaged Aerostructures", Ashley Spear, NSF Graduate Fellow, May, 2013 (expected).

28. "DDSim for Composite Structures", Brett Davis, May, 2013 (expected).

29. "Geometrical Simulation of Complete Process of Microstructurally Small Fatigue Cracking", Albert Cerrone, May 2013 (expected).